Reef for Fish Forever
Deployment of Artificial Reefs to Enhance Marine Fisheries Resources for the Sustainable Livelihood Development of Fisherfolk at Kalpakkam, Chenglepet District in Tamil Nadu, India.

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Abstract

Enhancing Marine Biodiversity and Livelihoods through Artificial Reefs: A Case Study from Tamil Nadu

Artificial reefs have emerged as a sustainable solution for marine biodiversity conservation and fisheries enhancement along the Tamil Nadu coast. This project successfully deployed 200 artificial reef structures across a 1,000 sq. m core area, leading to significant ecological and socio-economic benefits. The reefs provide habitats for marine species, increasing fish biomass by 3,000 to 5,000 kg per month and benefiting over 1,200 fishing families directly and indirectly.

The initiative has contributed to reducing fishing pressure, lowering fuel consumption, and mitigating CO2 emissions. By eliminating long-distance fishing, the project has led to an estimated daily greenhouse gas reduction of 10.5 metric tons and fuel cost savings of Rs. 37,500 per day. These efforts have bolstered sustainable fishing practices, providing fishers with a stable income of Rs. 15,000 to Rs.20,000 per month per family. Additionally, the reefs act as natural wave breakers, helping to mitigate coastal erosion and improve coastal resilience.

To ensure long-term sustainability, a reef management program is proposed, including scuba diving training for local youth to clean entangled nets and promote ecotourism. The PLANT organization is spearheading efforts to scale up this model with support from the Madras Atomic Power Station (MAPS) and Tamil Nadu Fisheries Department. Recognizing its success, the Government of India, MoEF&CC, and UNDP have integrated artificial reef deployment into national fisheries policy, with Tamil Nadu allocating Rs. 10 crores for further expansion.

This project serves as a replicable model for coastal biodiversity conservation and fisheries sustainability, offering valuable lessons for national and global artificial reef initiatives.

Keywords: Artificial reefs, marine biodiversity, sustainable fisheries, coastal conservation, livelihood

enhancement, Tamil Nadu. VMC- Village Monitoring Committee, Coral Reefs,

1. Introduction

1.1. Project Concept and Detailed Description

Tamil Nadu, located at the southeastern tip of the Indian Peninsula, is one of India's oldest maritime states. Its coastline accounts for approximately 15% of the country's total coastal length, playing a crucial role in the national economy due to its rich biodiversity and productive marine habitats. However, unsustainable and unregulated fishing, coupled with extensive agricultural and industrial activities along the coast, has placed immense pressure on coastal ecosystems. Additionally, rapid urbanization and frequent natural disasters have further exacerbated the degradation of these regions, leading to a significant decline in fish productivity, aquatic biodiversity, and the livelihoods of local fishing communities.

Artificial reefs—man-made concrete structures placed on the seabed—serve as a crucial intervention to restore marine biodiversity. These structures increase the surface area available for marine organisms, offering shelter for fish and lobsters to feed and breed. The project includes the deployment of three different reef modules:

1. **Ring Ornamental Fish Module**
2. **Ferro Concrete Triangle Reef Fish Module (Somosa Module)**
3. **Triangular Grouper Module**

In response to these challenges, the Participatory Learning Action Network and Training (PLANT), a non-governmental organization dedicated to the socio-economic advancement of Tamil Nadu's fishing communities, initiated a coastal ecosystem restoration program in 2004. By integrating modern scientific methods with traditional knowledge, the organization developed artificial reefs, evolving from conventional fish aggregation structures known as *Mullam*—historically created using tree branches or tires. These artificial reefs, also known as Fish Aggregation Devices (FADs), have been deployed across areas ranging from 1,000 to 5,000 square meters near 17 marine fishing villages in Kalpakkam and Mahabalipuram region. The initiative has been supported through corporate social responsibility (CSR) funding from NPCIL-MAPS, Kalpakkam (formerly in Kancheepuram district, now in Chengalpattu district).

This project, implemented with the support of the Village Monitoring Committee (VMC), promotes sustainable fishing practices by banning destructive fishing gear and regulating fishing activities. Over the years, these efforts have resulted in a significant increase in aquatic biodiversity and fish populations, leading to enhanced fish production and improved socio-economic conditions for the fishing communities.

1.2. Bio-geographical Significance

Tamil Nadu is the only state in India where both the Western and Eastern Ghats converge at the Nilgiri Hills. Biogeographically a part of the Deccan Peninsula, the state has a coastline of approximately 1,076 km, bordered by the Indian Ocean to the south and the Bay of Bengal to the east. Tamil Nadu is endowed with a diverse range of coastal and marine ecosystems, including mangroves, coral reefs, seagrass beds, sand dunes, beaches, mudflats, salt marshes, wetlands, estuaries, and extensive marine waters. Notably, it is home to India's first Marine Biosphere Reserve, the Gulf of Mannar Biosphere Reserve (GOMBR).

The coastal ecosystem of Chenglepet district provides a range of vital ecological services, including food supply, water resources, livelihoods, coastal protection, and carbon sequestration.[1] The region's aquatic fauna includes commercially valuable crustaceans and finfish, as well as ecologically significant species such as Olive Ridley turtles, otters, shrimps, resident and migratory birds, and several threatened marine species. Among these are the Milk Shark (*Rhizoprionodon acutus*), Seer Fish (*Scomberomorus commerson*), Sea Cucumber, and Sea Horse. *(Specific information on the aquatic biodiversity of Cuddalore district and the project areas should be verified and incorporated accordingly.)*

1.3. Need for the Initiative

By the 1990s, a significant decline in fish populations along the Tamil Nadu coast was observed. This decline was attributed to both environmental and human-induced factors. Erratic rainfall patterns, the closure of river mouths, and natural disasters, coupled with industrial and developmental activities leading to the discharge of pollutants into coastal waters, severely impacted marine ecosystems.

However, the most pressing threat to the coastal environment was the overexploitation of marine resources due to unregulated and unsustainable fishing practices. The use of non-selective fishing gear, such as trawlers,[2] caused extensive damage to coral

[1] http://www.indiaenvironmentportal.org.in/files/file/soer2.pdf

[2] *Trawling is a method of fishing that involves pulling fishing net through the water behind one or more boats. The net that is used for trawling is called a trawl. The boats that are used for trawling are called trawlers or draggers.*

reefs, sharks, sea turtles, and other vulnerable marine species, including the Milk Shark, Seer Fish, Sea Cucumber, False Trevally (*Lactarius lactarius*), and Sea Horse.

Following the 2004 tsunami,[3] a voluntary organization distributed numerous fiber-reinforced plastic (FRP) boats and fishing nets to support the livelihoods of the affected fishing communities.[4] However, this inadvertently contributed to increased juvenile fish harvesting, further depleting aquatic populations and leaving little opportunity for marine species to breed and regenerate.

2. Genesis of the Initiative, Its Objective, and Governance

Recognizing the ecological decline in the region, PLANT launched an initiative to restore the coastal ecosystem by deploying artificial reefs across 1,000 square kilometers along the Chenglepet district coastline near the fishing hamlet of Pudupattinam, while also implementing measures to curb unsustainable fishing practices.

The primary objectives of the initiative were to:

- Increase the biological population and diversity of inshore waters,
- Enhance the population of threatened species dependent on small fish stocks, and
- Improve livelihood opportunities for local fishing communities.

To ensure effective governance, a Village Monitoring Committee (VMC) was established to regulate and protect the artificial reef area while promoting awareness about sustainable fishing practices. The VMC also plays a crucial role in conflict resolution among fishermen, working in collaboration with local government officials. Through this system, fishing communities have implemented their own social control mechanisms, ensuring adherence to customary laws and practices for the conservation of fishery resources within the artificial reef zone.

2.1. Conservation and Management Initiatives by PLANT

The conservation initiative began with the designation of a 1,000-square-meter core area as an Indigenous and Community Conserved Area (ICCA), where 200 artificial reef structures were deployed for one fishing hamlet, expanding the available habitat to 1,000 square kilometers for marine organisms to colonize. Surrounding this core, a 5,000-square-meter secondary protected area was established, along with a 10,000-square-meter buffer zone, serving as a crucial coastal ecosystem reserve.

2.2. Concept of Artificial Reefs

Marine biological productivity can be significantly increased by expanding the seabed substratum, which provides an ideal habitat for colonizing organisms. Artificial reefs attract small fish initially, followed by larger predatory species. The abundant food supply and secured shelter within the reef structures create optimal conditions for breeding and sustaining aquatic populations.

Traditionally, fishermen have used a method known locally as *Mullam*, where large trees were submerged to serve as rudimentary fish aggregation devices. Building on this practice, the Village Monitoring Committee - VMC has implemented a sustainable fishing system that prohibits the use of unsustainable fishing gear, fiberglass-reinforced plastic (FRP) boats with gill nets, and other destructive fishing methods. To manage fishing pressure, the VMC enforces a roster-based rotation system, limiting the number of fishermen allowed in the fishing zone each day.

The artificial reefs also act as protective barriers for small-scale fishermen by safeguarding their fishing grounds within 5 nautical miles of the shore. The presence of these reef structures deters mechanized trawlers, as their nets become entangled in the reef, leading to financial losses for trawler owners. Consequently, the reef zone serves as an effective natural barrier against over exploitation of marine resources, contributing to coastal biodiversity conservation.

Furthermore, the VMC has successfully preserved the traditional *Padu* system—an equal distribution system for fishing grounds—across neighboring villages. This system promotes equitable access, collective social responsibility in fisheries management, and conflict resolution among fishing communities.

3. Impact of the Initiative

The collaborative efforts of PLANT and local communities have yielded significant ecological and

[3] The Great Sumatra earthquake of 26 December 2004 caused the Indian Ocean tsunami had a significant effect on the southern peninsular region of India and severely affected the coastal regions of state of Tamil Nadu

[4] Fiber Reinforced Plastic Boats

socio-economic benefits across the beneficiary villages.

3.1. Ecological Impact

a. The artificial reef has led to a marked increase in fish population size and species diversity. The newly established ecosystem now supports representatives from seven different phyla, comprising approximately 38 species, including polychaetous annelids, crustaceans, mollusks, coelenterates, and bryozoans. Fish species observed at the reef include carangids, rays, butterflyfish, squirrelfish, groupers, red snappers, catfish, and various small, colorful coral fish such as blue damsels, wrasses, and dumbheads. The estimated average shoal size is around 200 individuals per reef.
b. Samples collected from artificial reefs in 10 villages across Chenglepet district and other reef zones recorded a sessile epibenthic biomass of 2,586 to 3,998 g/m² on horizontal surfaces and 4,821 to 7,992 g/m² on vertical surfaces. The estimated average biomass was 1,983 g/m² on the exposed outer surface of concrete reef structures and 3,813 g/m² on the protected interior surface along the Bay of Bengal.
c. The deployment of 200 artificial reef structures is estimated to reduce annual carbon dioxide emissions by 732 to 2,000 kg.

d. Fossil fuel consumption by fishing vessels has decreased significantly. The estimated reduction in CO_2 emissions per boat per day is approximately 13.25 kg.

3.2. Socio-Economic Impact

a. The artificial reef ecosystem generates an estimated **$190,000** worth of biodiversity products and ecosystem services annually.

b. Fishermen operating in the artificial reef zone catch approximately **3,000 to 5,000 kg of fish per month**, supporting over **3,600 families** in Chenglepet district's fishing villages. The average monthly income of these fishermen has increased to **₹15,000 to ₹20,000**. ($177 to $236).

c. The close proximity of the fishing grounds within the artificial reef zone has led to economic savings by reducing fuel consumption and fishing time.

d. Upon arrival at the shore, women take the lead in auctioning and selling the fish in local markets. Additionally, they have engaged in community-driven environmental activities, such as planting trees, developing home herbal gardens, and using organic manure for cultivation.

e. The estimated revenue generated from fish catch within the reef zone is **₹2.5 to 3 lakh per month**, per village amounting to **₹25 to 30 lakh per annum**. This remarkable income reinforces the sustainability of fishing livelihoods and provides marginalized fishing families with economic security and dignity.

4. Sustainability and Partnerships

The coastline of Tamil Nadu, located on the southeastern coast of the Indian Peninsula, forms part of the Coromandel Coast along the Bay of Bengal and the Indian Ocean. Stretching 1,076 km (669 mi), it is the second-longest coastline in India after Gujarat. The Tamil Nadu coastline encompasses 591 fishing villages across 13 districts.

PLANT, in collaboration with the local community, received support for the project from various organizations, including Nuclear Power Corporation of India Limited of Madras Atomic Power Station - NPCIL MAPS, the Ministry of Environment, Forest and Climate Change, the Central Marine Fisheries Research Institute (CMFRI), the Central Institute of Brackish Water Aquaculture, the Marine Product Export Development Authority (MPEDA), the Central Institute of Fishery Technology (CIFT), Tamil Nadu State Fisheries, and the Ministry of Shipping, Zoological Survey of India, Fisheries Survey of India.

5. Scientific Sea Survey

Before deploying artificial reefs, a comprehensive scientific sea survey must be conducted to identify a suitable seabed location. The reefs should be placed in shallow waters at depths of 6 to 18 meters, within five nautical miles of the shore, to ensure adequate sunlight exposure for photosynthesis. To establish a sustainable fish colony and effectively conserve coastal biodiversity, a minimum of 200 structures per village is required.

To advance the reef project, PLANT NGO presented the success story of its artificial reef initiative to Madras Atomic Power Station (MAPS) in 2012. The

organization proposed that MAPS undertake an artificial reef project in the Kalpakkam region as part of its Corporate Social Responsibility (CSR) efforts to support the livelihoods of local fishermen.

After conducting an in-depth study, MAPS approved the implementation of an artificial reef project in Pudupattinam village as a pilot initiative in 2012. Following the project's success, as evidenced by increased fish catch and higher incomes for fishermen, demand for similar projects grew in neighboring villages. Encouraged by positive feedback from the local fishing community, MAPS expanded the initiative to multiple villages in Chenglepet district. Research indicated that 3 to 5 tons of fish were harvested in the reef area using hook-and-line fishing techniques. It was estimated that each village generated monthly fish catches valued at approximately **₹2.5 to 3 lakhs**. While fish stock availability in the reef zone remained consistent, fishermen could only operate for about eight months each year due to rough sea conditions and fluctuating ocean currents. The underwater video study observed and estimated that 50 tons of diverse marine species are consistently present in the artificial reef zone. To date, Madras Atomic Power Station has However, the tsunami's seismic waves severely damaged this habitat, significantly reducing fish stocks and forcing fishermen to venture farther offshore in search of viable fishing grounds.

Recognizing artificial reefs as a viable solution to restoring fish stocks in nearshore waters, local fishermen urged MAPS to expand its reef deployment efforts in the Kalpakkam and Mahabalipuram regions. Responding to their request, MAPS extended its support to 17 neighboring fishing villages, significantly supported 17 fishing villages in the Kalpakkam and Mahabalipuram regions, deploying a total of 3,450 reef structures within five nautical miles of the shoreline.

A significant milestone of this initiative was its recognition by the Ministry of Environment and Forests under the UNDP GEF SGP project, which was honored with the UNDP India Biodiversity Award in 2016. Additionally, Madras Atomic Power Station received the prestigious Green Tech Award for its contributions to marine conservation.

6. Restoration of Natural Fishing Grounds

A study conducted in the Kalpakkam and Mahabalipuram regions revealed that fishermen practicing hook-and-line fishing required additional reef structures for sustainable fish harvesting. Before the 2004 tsunami, these fishermen relied on nearby fishing grounds within a five-nautical-mile radius. The seabed in this area was characterized by rocky and sandy substrates, with accumulations of barnacles and seashells that naturally fostered fish breeding.

enhancing marine biodiversity and sustaining local livelihoods. The reefs were fabricated in the fishing villages and deployed at the bottom of the sea by using the FRP boats and Marine Sail Vessel like Barge. The following Google map and table outlines the number of beneficiary villages, while the accompanying Google Map provides the latitude and longitude of each deployment site. Each Fishing village 200 to 210 reefs were deployed at the off shore of Kalpakkam and Mahabalipuram regions.

Fig I

Geographical spread

The below table indicates the consolidated reef sites and total number of reef deployed in the contiguous area in Chengalpattu districts.

Table I

Sl. No	Name of the village	No. of Reefs	Latitude	Longitude
1	Pudupattinam	210	N- 012°.27.814	E- 080°.11.684
2	Meyyur	210	N- 012°.31.641	E- 080°.12.493
3	Sadras North	210	N- 012°.29.919	E- 080°.12.048
4	Sadras South	210	N- 012°.29.691	E- 080°.12.225
5	Uyyali Kuppam	210	N- 012°.27.232	E- 080°.11.818
6	Kokilamedu	200	N- 012°.34.436	E- 080°.13.367
7	Pudu Edaiyur	200	N- 012°.39.017	E- 080°.14.939
8	Pattipulam	200	N- 012°.40.314	E- 080°.14.794
9	Pudu Kalpakkam	200	N- 012°.43.441	E- 080°.16.325
10	Nemili Kuppam	200	N- 012°.42.288	E- 080°.16.328
11	Kattu Kuppam	200	N- 012°.41.022	E- 080°.15.828
12	Devaneri	200	N- 012°.37.936	E- 080°.14.425
13	Venpurusam	200	N- 012°.35.468	E- 080°.13.705
14	Pudu Nadu Kuppam	200	N 12° 23' 258"	E 080° 08' 523"
15	Kadalur Chinna Kuppam	200	N 12° 25' 690"	E 080° 10' 567"
16	Angalamman Kuppam	200	N 12° 24' 271"	E 080° 08' 954"
17	Kadalur Ali Kuppam	200	N 12° 24' 250"	E 080° 09' 156"
	Total	3450		

7. Implementation Process

Intervention Strategies and Activities:

1. Conduct a benchmark survey on population structure, socioeconomic conditions, and livelihood status in the selected fishing villages.
2. Engage with Panchayat leaders to discuss the technologies and techniques to be introduced for community benefit and planning.
3. Form various committees for the execution and supervision of different program components, involving both villagers and PLANT representatives.
4. Fabricate the required number of artificial reef structures with technical support from PLANT.
5. Conduct a survey to identify suitable seabed locations for reef deployment, in collaboration with CMFRI and PLANT.
6. Deploy artificial reefs at the selected sites under the supervision of PLANT, with active participation from the fishing community.
7. Monitor and study the maturation process of artificial reefs to determine the optimal period for fish harvesting.
8. Introduce hook-and-line and trap fishing methods to fishermen, with training support from CFT Cochin and traditional trap fishers from Kilakarai.
9. Train fishermen to fabricate their own hook-and-line and trap fishing gear.
10. Assess fish catch composition and effort in both artificial reef areas and non-reef areas for comparison.
11. Introduce appropriate post-harvest methods, such as ice boxes and deep freezers, through linkages with MPEDA.
12. Facilitate market access for fresh fish, dried fish, and value-added products through women's Self-Help Groups (SHGs).
13. Conduct a mid-term assessment of project progress and perform another socioeconomic survey at the end of the first year.
14. In the second year, continue monitoring and evaluate the socioeconomic impact of the project.
15. Develop withdrawal strategies to ensure self-sustainability of the initiative by the community.

8. Monitoring and Evaluation Process Follow-up Programme

After the deployment of reefs, the PLANT team conducted regular field visits to all beneficiary villages to monitor the reef locations. Fishermen were advised to refrain from any fleet operations or fishing activities for six months, a designated incubation period allowing biological maturation. During this time, the reefs developed biological films consisting of algae, barnacles, ascidians, and other marine organisms, enhancing biomass production and attracting a variety of fish species for reproduction. Fishing activities were recommended only after 9 months, in the ninth month post-deployment. Additionally, fishermen were instructed never to use inappropriate fishing gear in the reef zone to ensure long-term conservation.

PLANT conducted a post-impact assessment of the artificial reef project using underwater video surveys. Professional scuba divers were engaged to document reef maturation and biological development. The underwater video footage is included in the project report. The Artificial Reef Monitoring (ARM) committee regulates fishing activities in the reef zone, allowing only 10 boats at a time to ensure sustainable use of biological resources. Each boat is permitted to catch between 10 and 15 kg of fish per trip to prevent overexploitation. Additionally, fishermen are encouraged to contribute 10% of their earnings to the village Panchayat as a community fund for future development initiatives.

9. Key Challenges Addressed

Key challenges include securing additional funding to replicate this project in other coastal states, improving coastal biodiversity, and enhancing marine fisheries resources. Price inflation and natural calamities also pose challenges to implementation. A dedicated government budget for large-scale deployment is recommended. Coastal industries should consider

adopting artificial reef projects as part of their CSR initiatives, and state pollution control boards should mandate such projects in their consent orders. Furthermore, community-led monitoring strengthens project sustainability.

10. **Impact Created**

High-resolution photographs, statistical data, and success stories from beneficiaries will be included to illustrate the project's impact. If available, detailed analysis and case studies will highlight the improvements in marine biodiversity and socioeconomic benefits to the fishing community.

11. **Biological Impact**

Within six months of installation, artificial reefs fostered bacterial bio-films, algae, seaweeds, barnacles, sponges, corals, crustaceans, soft and hard corals and various fish species. These developments significantly enriched marine biodiversity and enhanced fishery stocks. Underwater videography conducted by PLANT revealed an abundance of marine life, including rare species and ornamental fish. Notably, the presence of white and pink bush coral (Oculina varicosa) and octocorals and abundance of sea fans was observed, providing crucial habitat for commercially valuable fish species. These slow-growing corals, likened to underwater redwood forests, contribute to a unique and biologically diverse ecosystem previously undocumented off the Chenglepet coast.

12. **Result Indicators for the Deployment of Artificial Reefs**

a) A primary core surface area of 1,000 sq. m is established as an Indigenous and Community Conserved Area (ICCA) for biomass production, supported by 200 artificial reef structures within a single artificial reef zone.
b) This 1,000 sq. m area provides space for settlers and foulers to colonize, enhancing biodiversity in the artificial reef installation site.
c) A secondary core protected area of 5,000 sq. m is created, supporting secondary and tertiary producers within a short period of six months.
d) A buffer zone of 10,000 sq. m is established, contributing to coastal ecosystem conservation and supporting a diverse biomass.
e) 10,000 sq. m of dedicated space is available for the production of sustainable biomass, free from the negative impacts of mechanized bottom trawling within the artificial reef zone.
f) Each artificial reef structure produces between 2.5 kg and 5 kg of biomass per square meter per year.
g) A single artificial reef structure can sequester between 3.66 kg and 10 kg of CO2 annually.
h) The deployment of 300 artificial reefs has led to a reduction in annual CO2 emissions by 1,098 to 3,000 kg.
i) Significant savings in fossil fuel consumption and reduction in fishing time are achieved due to the proximity of the artificial reef fishing ground.
j) Each fishing boat saves 5 liters of fossil fuel per day, as the fishing ground is located within 5 km of the fishing village, eliminating the need for long-distance fish hunting.
k) Consequently, the CO2 reduction per boat per day is estimated at approximately 13.25 kg.
l) With 150 boats operating daily, the total CO2 reduction amounts to 1,987.5 kg per day.
m) Additionally, these 150 boats collectively save 750 liters of diesel daily, as they fish near the artificial reef zone, utilizing wind power or manual rowing whenever feasible.
n) The estimated daily Greenhouse Gas (GHG) reduction is 10.5 metric tons.
o) The estimated fuel cost savings per day is Rs. 37,500/- ($750/-) due to reduced fuel consumption.

This structured deployment of artificial reefs demonstrates significant environmental and economic benefits, promoting sustainability in coastal fisheries and marine conservation.

13. **Economic Benefit**

As an outcome, fishery resources have significantly increased over a maturation period of one year. Fishermen operating in the artificial reef zone catch approximately 3,000 to 5,000 kg of fish per month. This innovative intervention continues to support 200 to 300 families directly in a single village, while an additional 1,200 families benefit indirectly.

The Tamil Nadu State Fisheries Department has recognized the efforts of the federation and has

standardized this participatory fabrication and deployment model for replication in other locations. As a result of this project's overwhelming success, the Government of Tamil Nadu has sanctioned more artificial reef projects across the state.
The fishing effort within a single artificial reef zone has increased to 3 to 5 tons per month, generating an estimated revenue of **₹2.5 to 3 lakhs**, benefiting 1,200 families. This translates to an average income of Rs. 15,000 to Rs.20,000 per family, providing a sustainable livelihood.

This initiative has significantly improved the well-being and economic status of the fishing community, paving the way for sustainable fishing and livelihood development. Additionally, recognizing its broader climate change mitigation potential, both the state government and corporate CSR initiatives are actively promoting artificial reef projects to support fishing communities in Tamil Nadu while addressing environmental concerns.

14. Management and Scaling Up of Artificial Reefs

To ensure the long-term sustainability of artificial reefs, it is essential to establish regular maintenance and management in the installed areas. The presence of fishermen from other villages who fish in the reef zone using inappropriate nets poses a risk of damaging the reefs. When fishing nets become entangled in the reef structures, they can cause mass fish mortality, leading to foul odors and forcing marine species to migrate away from the area.

As a preventive measure, it is proposed to train village youth in scuba diving, enabling them to periodically clean entangled nets from the reef zone. Additionally, they can promote scuba diving as an ecotourism activity, generating an alternative source of income. The PLANT organization plans to introduce this initiative in the next phase of its project, submitting a proposal to Madras Atomic Power Station (MAPS) as part of its youth skill development program. The project's location in Mahabalipuram on East Coast Road (ECR) offers vast potential for ecotourism, which could further contribute to reef conservation efforts.

The implementing agency, PLANT, is also advised to conduct regular site visits to beneficiary villages to assess the project's impact through fish catch data collection, training programs, and conflict resolution mechanisms. Additionally, MAPS is encouraged to commission a scientific impact assessment study to evaluate the long-term effectiveness of artificial reefs.
Several other villages have requested MAPS to support new artificial reef projects. The PLANT organization has encouraged village Panchayat to submit petitions to the MAPS CSR team, advocating for further expansions. Given the success of this community-driven, science-based initiative, it is recommended that Nuclear Power Corporation of India Limited (NPCIL) replicate this artificial reef model in other NPCIL coastal project sites to enhance marine biodiversity and fisheries resources.

15. Future Prospects and National Impact

Scaling up this project based on lessons learned from previous implementations is critical for expanding its benefits across coastal states in India and globally. Systematic documentation of successful models and findings could facilitate the development of national fisheries policy guidelines, enabling widespread replication. This initiative has the potential to boost India's fish export industry, contribute to national GDP growth, and enhance food security.[5] In 2024, The fisheries sector contributes approximately 1.09% to India's total Gross Value Added (GVA) at constant prices, and over 6.724% to the agricultural GVA. In comparison, in 2010-11, the fisheries sector contributed 0.79% to India's total GDP and 4.39% to the agriculture sector's GDP[6]. This significant growth is attributed to the introduction of innovative projects such as artificial reefs, open-sea cage culture, and aquaculture farming activities, which have enhanced marine sector productivity.

The artificial reef project has significantly transformed the coastal ecosystem, promoting marine biodiversity conservation and sustainable fisheries in Kalpakkam and Mahabalipuram. It has also improved livelihoods, empowering fishing women by allowing them to sell fresh fish at fair prices, eliminating middlemen, and fostering savings habits. Additionally, village panchayats have established common funds, with fishers contributing 10% of their income to support local development initiatives.

Beyond fisheries, the reefs serve as natural barriers against seismic waves, mitigating coastal erosion and protecting fishing villages. This project has truly made a global impact on coastal conservation and community livelihoods.

Dr. R.T. John Suresh, founder of PLANT and an expert in artificial reef projects, has presented this successful model at national and international forums, exhibitions, and conferences. As a result, the Indian

[5] https://www.fao.org/fishery/en/facp/ind?lang=es

[6] https://dof.gov.in/sites/default/files/2020-01/India%20Profile%20updated_0.pdf

government, through the Ministry of Environment, Forest and Climate Change (MoEF&CC) and UNDP, has adopted this project as part of national fisheries development policy. The Tamil Nadu Fisheries Department has allocated separate budget to scale up artificial reef projects along the Tamil Nadu coast.

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These below references are closely related to your article on artificial reefs. They cover key aspects relevant to your study, including:

1. *Ecological Benefits – How artificial reefs enhance biodiversity, fish biomass, and marine conservation.*
2. *Fisheries Enhancement – The role of artificial reefs in increasing fish catch and supporting sustainable fishing.*
3. *Socioeconomic Impacts – The impact on local fishing communities, livelihoods, and economic benefits.*
4. *Carbon Sequestration & Climate Change – How artificial reefs contribute to reducing CO_2 emissions.*
5. *Reef Management & Sustainability – Strategies for maintaining artificial reefs, preventing damage, and scaling up.*

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Pictures

Before-after the deployment of Reefs

After Deployment (three year old reef)

Fish stock availability in the reef area


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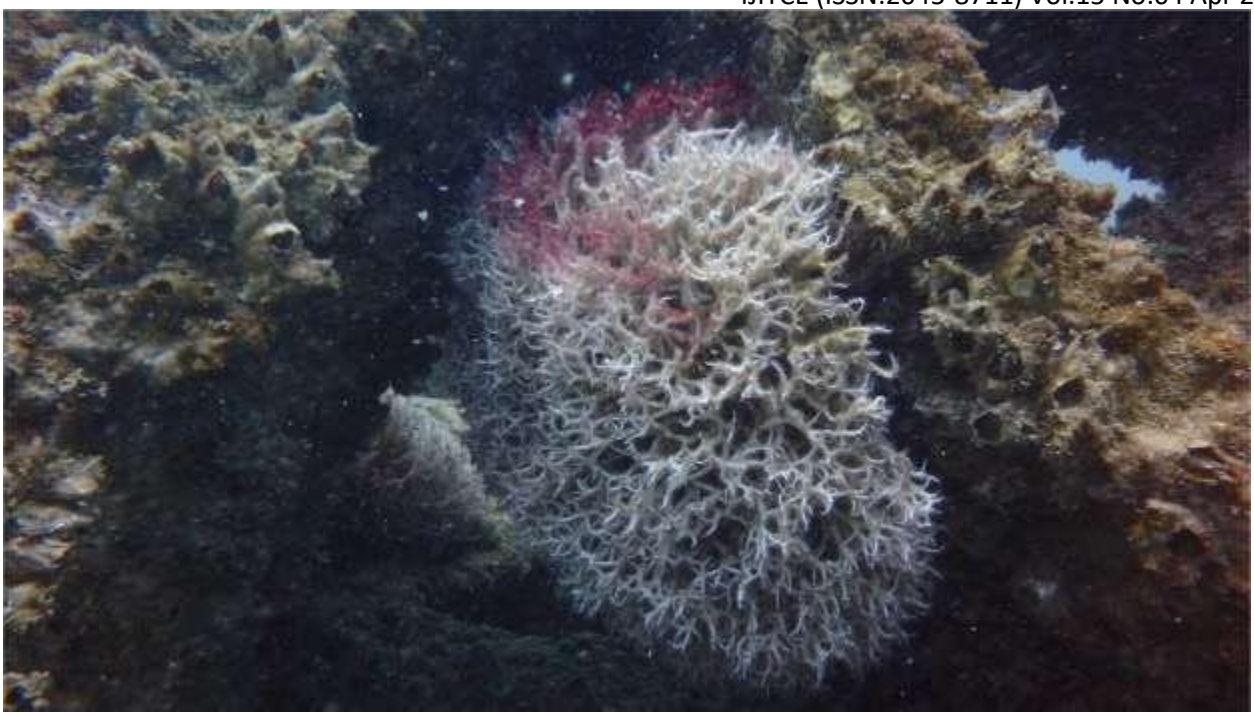
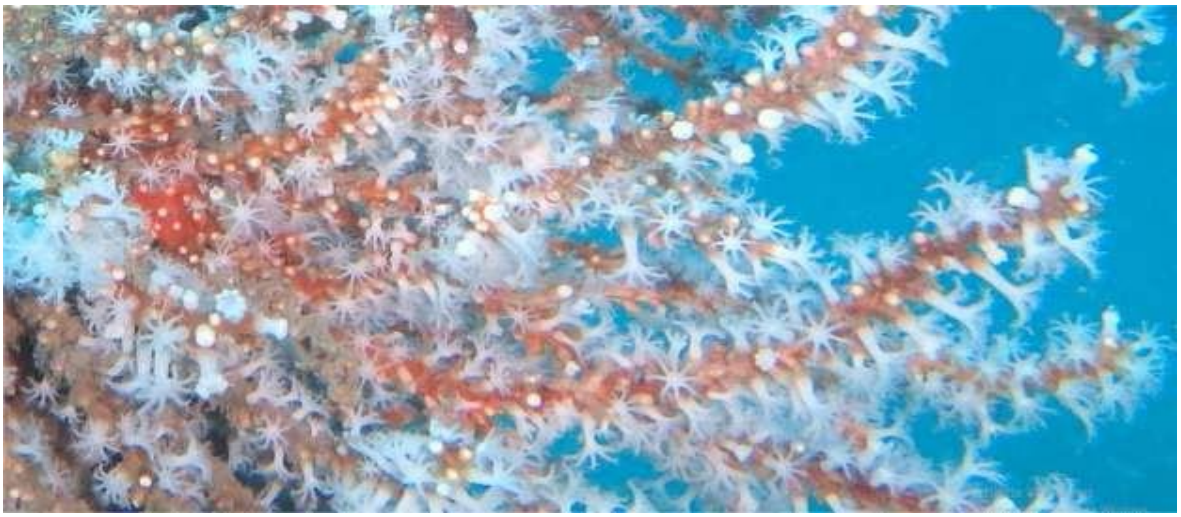


Oculina Coral and rare species like Lion fish and sea feather settled in the reef area

White Telesto, an octocoral (*Carijoa riisei*), has settled on the reef



Chairman and Managing Director inaugurating the Artificial Reef Deployment at Kalpakkam.

Reefs deployed to save power plant house 50 marine species

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A series of concrete blocks — artificial reef — deployed a few kilometres into the sea by the state fisheries department has turned out to be a good sign for the fishermen in Nemmilikuppam

D Karunakaran, 40, of Nemmilikuppam was among the 160 fishermen who would often return home after spending the day at sea with a catch that barely would sell for ₹1,000. However, that changed in the last few years after artificial reefs became home to many fish.

Fishermen claim to have a catch worth at least five times more than what they used to earn earlier.

The artificial reefs were deployed between 2012 and 2020 around 9km into the sea at 18m depth across a 30km stretch from Pudukalpakkam near Kovalam in the north to Angalamman Kuppam near Koovathur in the south covering Madras Atomic Power Station (MAPS) at Kalpakkam, the township and 17 other coastal villages. The blocks, expected to protect the coast from rough waves, and erosion, are now home to nearly 45 marine species, including commercially important fish varieties. The reef deployment was carried out as part of a project funded by MAPS and implemented by Chennai-based NGO Partici- patory Learning Action Network and Training (PLANT).

"It was part of our CSR activities. The reefs were deployed along the coast from the power plant to the township a few years ago and now it's home to numerous species," said Shub- h a Murthy, technical services group, MAPS.

RT John Suresh, the founder of PLANT, said a recent underwater survey showed that the reefs have attracted many rare, commercially important and ornamental species.

"A variety of the white and pink hard coral reefs otherwise called Oculina Varicosa or the ivory tree corals are growing in the reef structures in a non-coral region. These corals are attracting fishes including commercially important fish species to the region as they act as a habitat," he said.

It all started with reefs shaped in circular, triangles and rectangles being first deployed in one village in 2012 and later extended to 17 coastal villages in and around Kalpakkam. Around 200 concrete blocks have been deployed near each coastal village. Suresh said soon after the deployment the reefs saw algae, and microorganisms started settling, which began attracting other marine species. Eventually, they observed seaweeds, barnacles, ascidians, sponges, hard and soft corals, gorgonids, starfishes, sea urchins, sea cucumbers, bivalves, chunks, crabs, lobsters, other crustaceans followed by a variety of fishes and other vertebrates.

VARIETIES OF FISH

Nemmelikuppam fisherman Karunakaran said they are seeing more fish varieties like **paarai (mackerel) kalava (reef cod), vavval (Pomfret) and kilicha (Perch)** now compared to before the reefs were deployed when they would only find crabs and thumbli (lizardfish) fish. "Also, we don't have to venture too far into the sea because we get good yield near the reefs around 4km from the coast," he said.